

What is claimed is:

- 1 1. A semiconductor device, comprising a substrate having a substrate surface, a barrier film  
2 on the substrate surface, and a single crystal transition metal on the barrier film.
- 1 2. A semiconductor device according to claim 1, wherein the barrier film has a thickness less  
2 than approximately 250Å.
- 1 3. A semiconductor device according to claim 1, wherein the barrier film has a thickness less  
2 than approximately 100Å.
- 1 4. A semiconductor device according to claim 1, wherein the barrier film has a thickness in  
2 the range of approximately 20 to approximately 75Å.
- 1 5. A semiconductor device according to claim 1, wherein the metal comprises an elemental  
2 transition metal.
- 1 6. A semiconductor device according to claim 1, wherein the transition metal is selected from  
2 the group consisting of copper, silver, gold and platinum.
- 1 7. A semiconductor device according to claim 1, wherein the transition metal comprises  
2 copper.

1 8. A semiconductor device according to claim 1, wherein the barrier film comprises a  
2 heteroepitaxial film structure comprising a monolayer of metal atoms selected from barium atoms,  
3 strontium atoms, and cesium atoms, singly or in combinations thereof, located on said surface of  
4 said substrate, and a homoepitaxial portion comprised a metal halide selected from barium halide,  
5 strontium halide and cesium halide located between the monolayer and the metal.

1 9. A semiconductor device according to claim 1, wherein the substrate is selected from the  
2 group consisting of single crystal silicon, polycrystalline silicon, SOI, SOS, gallium arsenide,  
3 silicon carbide, indium phosphide, gallium nitride, aluminum nitride, germanium, indium  
4 antimonide, lead telluride, cadmium telluride, mercury-cadmium telluride, lead selenide, lead  
5 sulfide, and tertiary and quaternary combinations of these materials.

1 10. A semiconductor device according to claim 1, wherein the substrate comprises single  
2 crystal silicon.

1 11. A semiconductor device according to claim 1, wherein the substrate comprises single  
2 crystal gallium arsenide.

1 12. A semiconductor device comprising a single crystal substrate having a substrate surface, a  
2 barrier film on the substrate surface, where said barrier film comprises homoepitaxial metal halide  
3 and said barrier film having a thickness less than approximately 100Å, and single crystal metal  
4 directly on the metal halide.

1 13. A semiconductor device according to claim 12, wherein the substrate is selected from the  
2 group consisting of silicon and silicon oxide, the metal halide is selected from the group consisting  
3 of barium halide and strontium halide, and said metal is selected from the group consisting of  
4 copper, gold, silver, and platinum.

1 14. A process for making a semiconductor device comprising the steps of:  
2 forming, on a surface of a substrate material, a barrier film; and  
3 forming a single crystal transition metal on the barrier film.

Sub 7  
1 15. A process for making a semiconductor device according to claim 14, wherein the forming  
2 of the barrier film comprises the following substeps:  
3 vapor depositing a metal halide on the cleaned heated substrate surface at a temperature of  
4 500 to 700°C, in a vacuum having a background pressure of less than approximately  $10^{-11}$  Torr,  
5 and wherein the metal halide deposition is conducted at a rate permitting the metal halide vapor to  
6 react with the substrate surface to form a monolayer of metal atoms selected from barium atoms,  
7 strontium atoms, and cesium atoms, singly or in combinations thereof, on said surface of said  
8 substrate; and

9 continuing, after forming the monolayer, the vapor depositing of the metal halide to form a  
10 metal halide layer regime upon the monolayer until the desired barrier film thickness has been  
11 achieved.

1 16. A process for making a semiconductor device according to claim 14, wherein the forming  
2 of the single crystal transition metal on the barrier film comprises depositing a transition metal on  
3 the barrier film concurrent with heating the substrate and barrier film surface to a temperature  
4 effective to cause the transition metal to assume a monocrystalline structure.

1 17. A process for making a semiconductor device according to claim 14, wherein the forming  
2 of the single crystal transition metal on the barrier film comprises the substeps of depositing a  
3 transition metal on the barrier film at a temperature below which the metal forms with a single  
4 crystal structure, and then annealing the resulting metallized substrate at a temperature effective to  
5 cause the transition metal to assume a monocrystalline structure.

1 18. A process for making a semiconductor device according to claim 14, wherein the forming  
2 of the single crystal transition metal on the barrier film comprises depositing a transition metal on  
3 the barrier film concurrent with heating the substrate and barrier film surface to approximately  
4 375°C or higher.

1 <sup>13</sup>19. A process for making a semiconductor device according to claim <sup>12</sup>18, wherein the transition  
2 metal comprises copper.

20. A process for making a semiconductor device according to claim 14, wherein the forming of the single crystal transition metal on the barrier film comprises the substeps of depositing a transition metal on the barrier film at a temperature below 375°C, and then annealing the resulting metallized substrate at a temperature of 375°C or higher.

1 | 5-21. A process for making a semiconductor device according to claim 20, wherein the transition  
2 | metal comprises copper.

22. A process for making a semiconductor device according to claim 14, wherein the barrier film comprises a homoepitaxial portion comprised a metal halide selected from barium halide, strontium halide, and cesium halide, located between the monolayer and the transition metal.

23. A process for making a semiconductor device according to claim 14, wherein the homoepitaxial portion of the barrier film is selected from  $\text{BaF}_2$ ,  $\text{BaCl}_2$ ,  $\text{SrF}_2$ ,  $\text{SrCl}_2$ ,  $\text{CsF}$ , or  $\text{CsCl}$ .

1 24. A process for making a semiconductor device according to claim 14, wherein the barrier  
2 film has a thickness of less than 100Å.

25. A process for making a semiconductor device according to claim 14, wherein the barrier film has a thickness ranging from approximately from 20Å to approximately 75Å.

1 26. A process for making a semiconductor device according to claim 14, wherein the transition  
2 metal is selected from the group consisting of copper, silver, gold and platinum.

1 27. A process for making a semiconductor device according to claim 14, wherein the transition  
2 metal comprises copper.

1 28. A process for making a semiconductor device according to claim 14, wherein the substrate  
2 material comprises a semiconductor.

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